Real-time gas imaging with the gas cloud imager (GCI)

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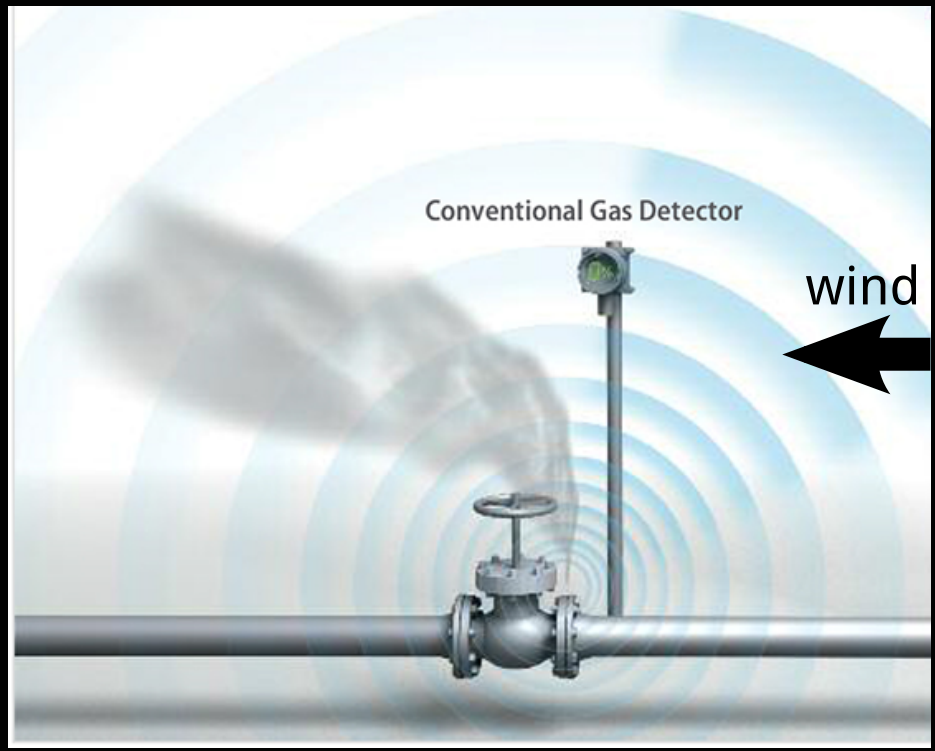
Detection of gas clouds

Safety alarms: flammable and toxic gases are serious hazards. Every year, several major facilities experience large-scale explosions and toxic-gas releases.

Emissions monitoring: facility emissions cause financial loss and cause environmental hazards. Drilling rig sites, pipelines, and processing facilities all leak, but many facility owners lack the equipment to find many of the leaks. And the recent fracking boom has hightened attention towards how these leaks may be affecting the environment.

Standard gas sensors

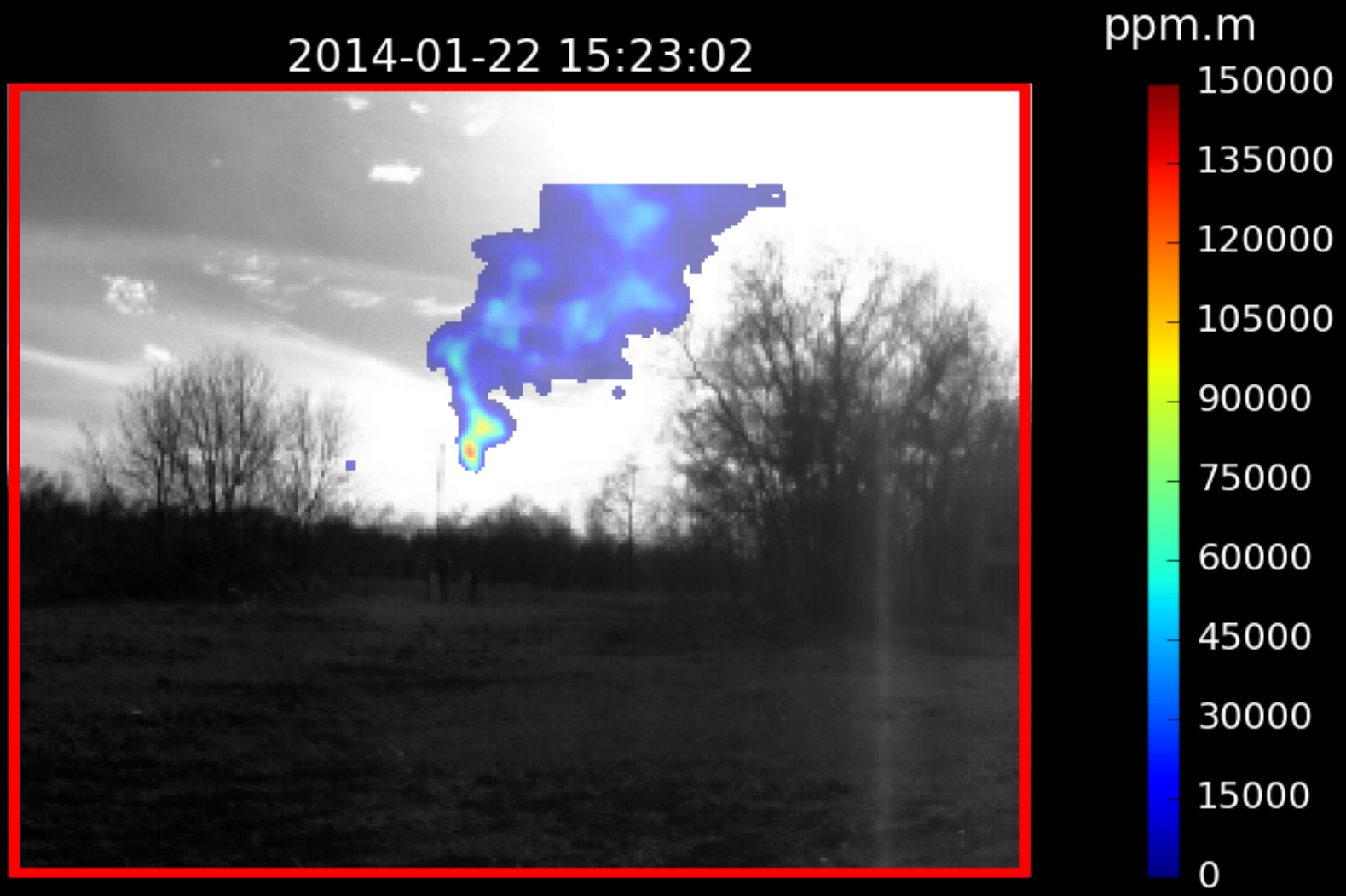
The status quo for gas sensing is to populate a facility with single-point gas sensors to sparsely sample the surrounding air.



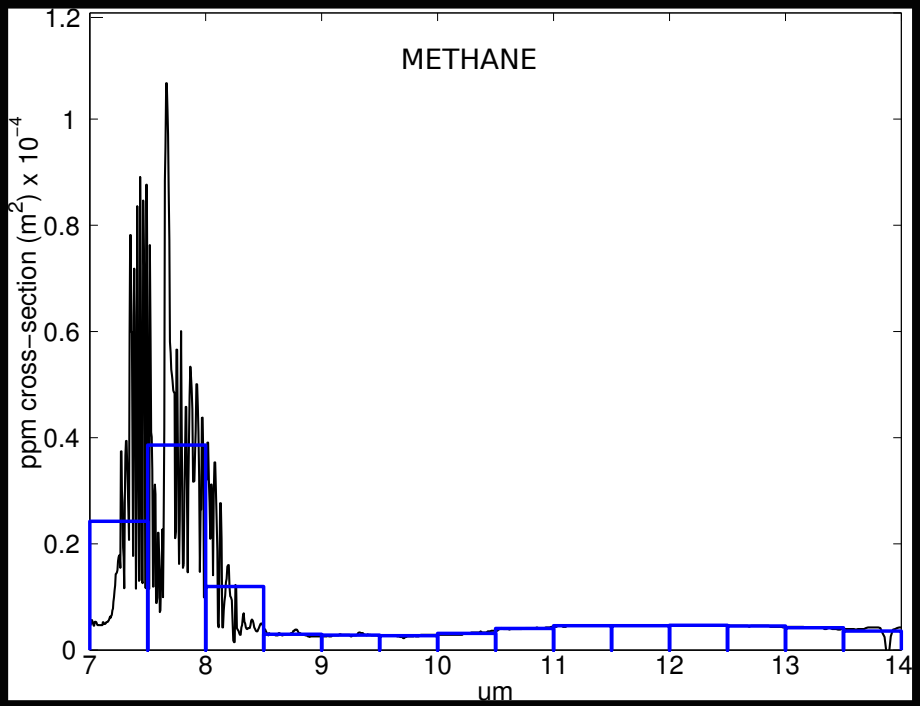
Left figure from `http://www.generalmonitors.com/Gas-Detectors/IR700-Point-IR-Carbon-Dioxide-Gas-Detector/p/000140006800001002`.

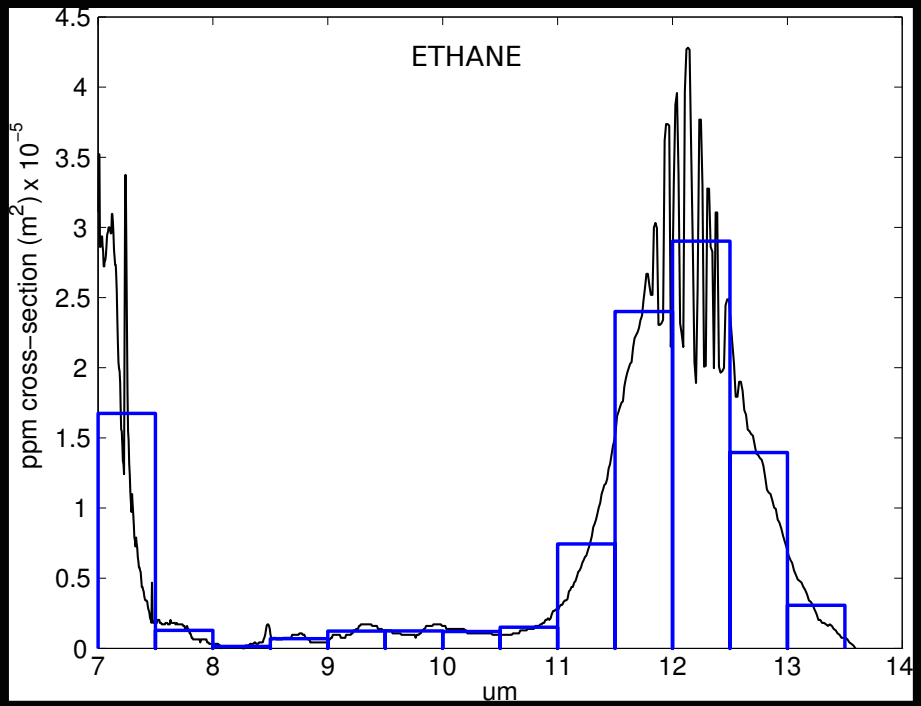
Right figure adapted from `http://www.gmigasandflame.com/article_may2014_observer_i_fig2.html`

Gas cloud imaging



Passive IR absorption spectroscopy





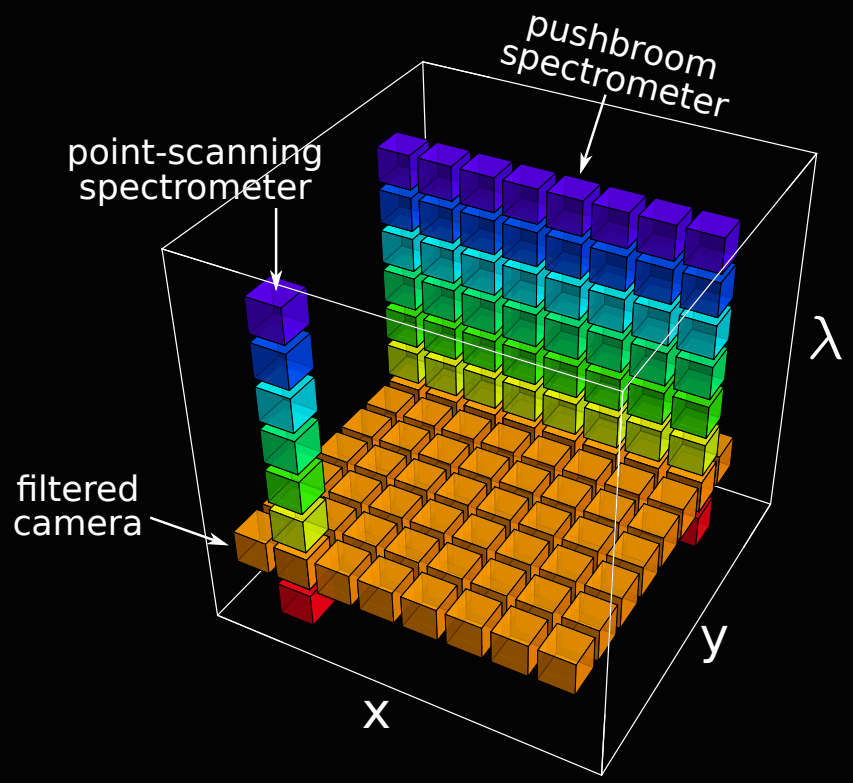
Absorption cross-section spectra of methane and ethane (from the NIST infrared spectral database), shown in high resolution (black), and downsampled to low-resolution spectra (0.5 µm per channel) (blue).

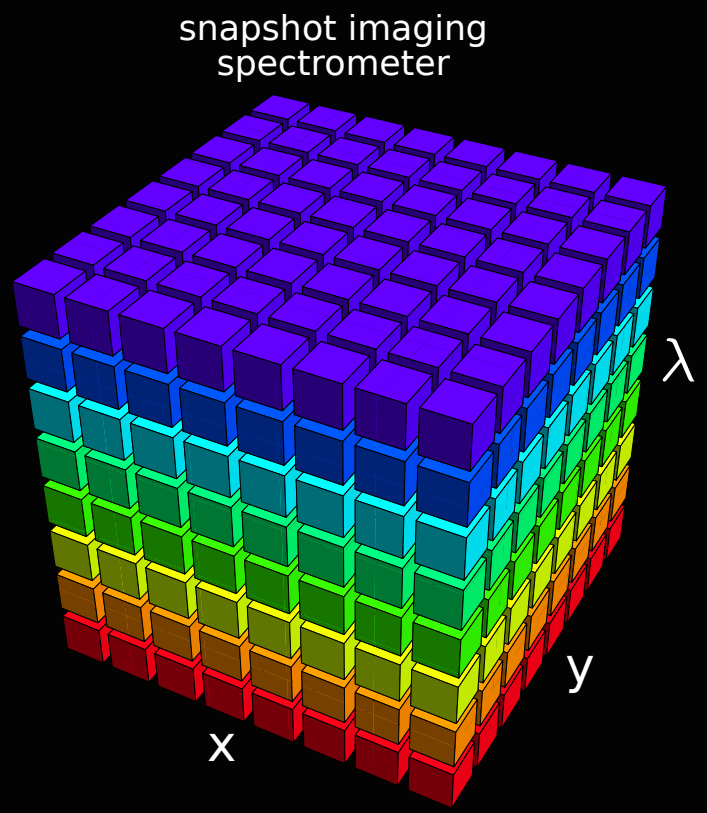
Historical difficulties with gas cloud imaging

Although the technique of passive IR imaging of gases was proven in the lab decades ago, implementation in industrial settings has been frustrated by issues of

- poor SNR
- environmental interference: steam, varying sunlight, people, etc.
- motion artifacts: gas clouds are not static, measurements too slow

Scanning vs. snapshot





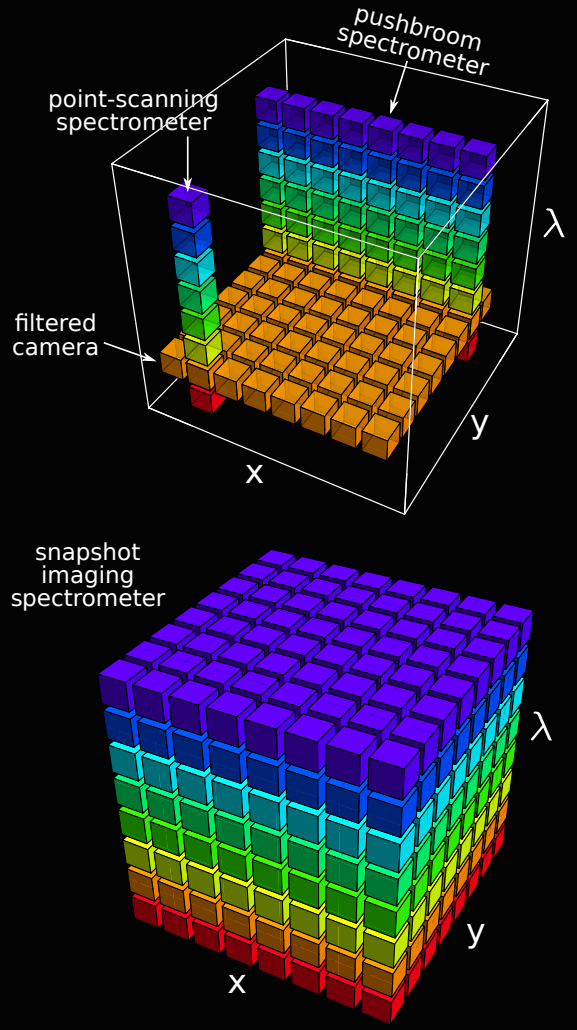
- Low light collection
- Artifacts due to object motion during scan
- Higher power consumption

- Improved light collection
- Reliable (no moving parts)
- Low size, weight, and power
- No motion artifacts

The snapshot advantage

Scanning systems collect light from only a portion of the datacube at a time; the remaining light is wasted. For an example datacube of dimensions $(N_x, N_y, N_\lambda) = (500, 500, 100)$:

- A point scanning system sees only 100 voxels of the datacube at any given time, so efficiency $= 1/(500 \times 500)$.
- A pushbroom (line scanning) system sees a 500×100 slice of the datacube at a given time, so efficiency $= 1/500$.
- A filtered camera sees a 500×500 slice at a time, so efficiency $= 1/100$.
- A snapshot system has efficiency $= 1$.



*Hagen *et al.*, "The snapshot advantage," Opt. Eng. **51**: 111702 (2012).

Rebellion photonics' GCI

GCI advantages

The advantages of the GCI's snapshot architecture include:

- No motion artifacts
- Allows video analytics
- Uncooled sensor: longer operational lifetime, low maintenance, and low cost

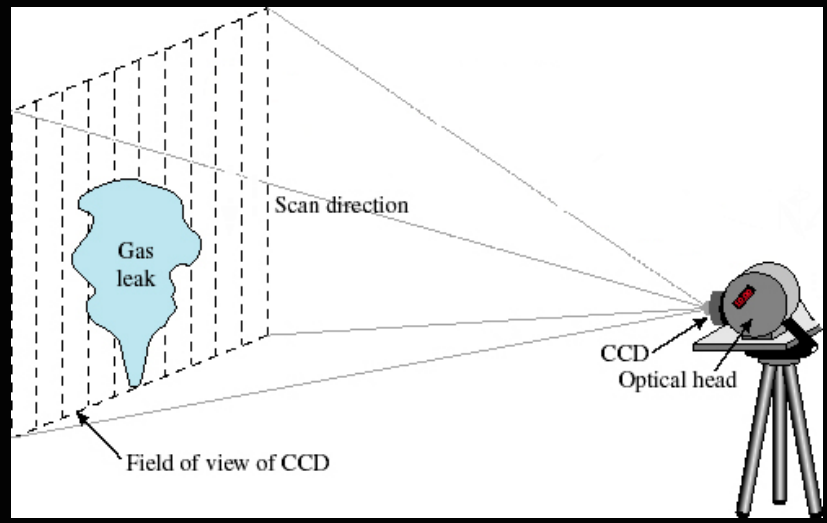
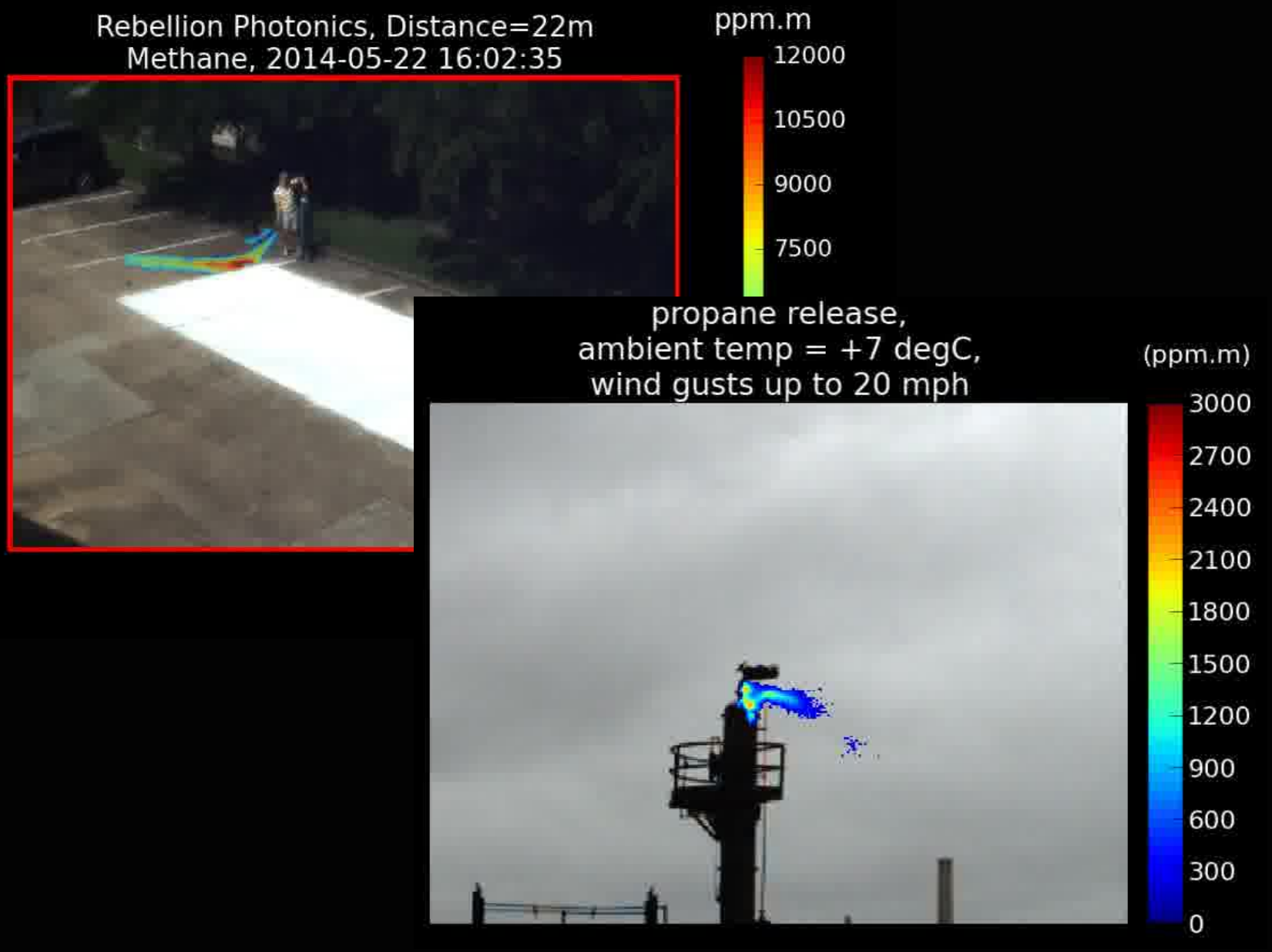


Image adapted from `http://iopscience.iop.org/1367-2630/8/2/026/fulltext/`.

User interface

User interface

Example data

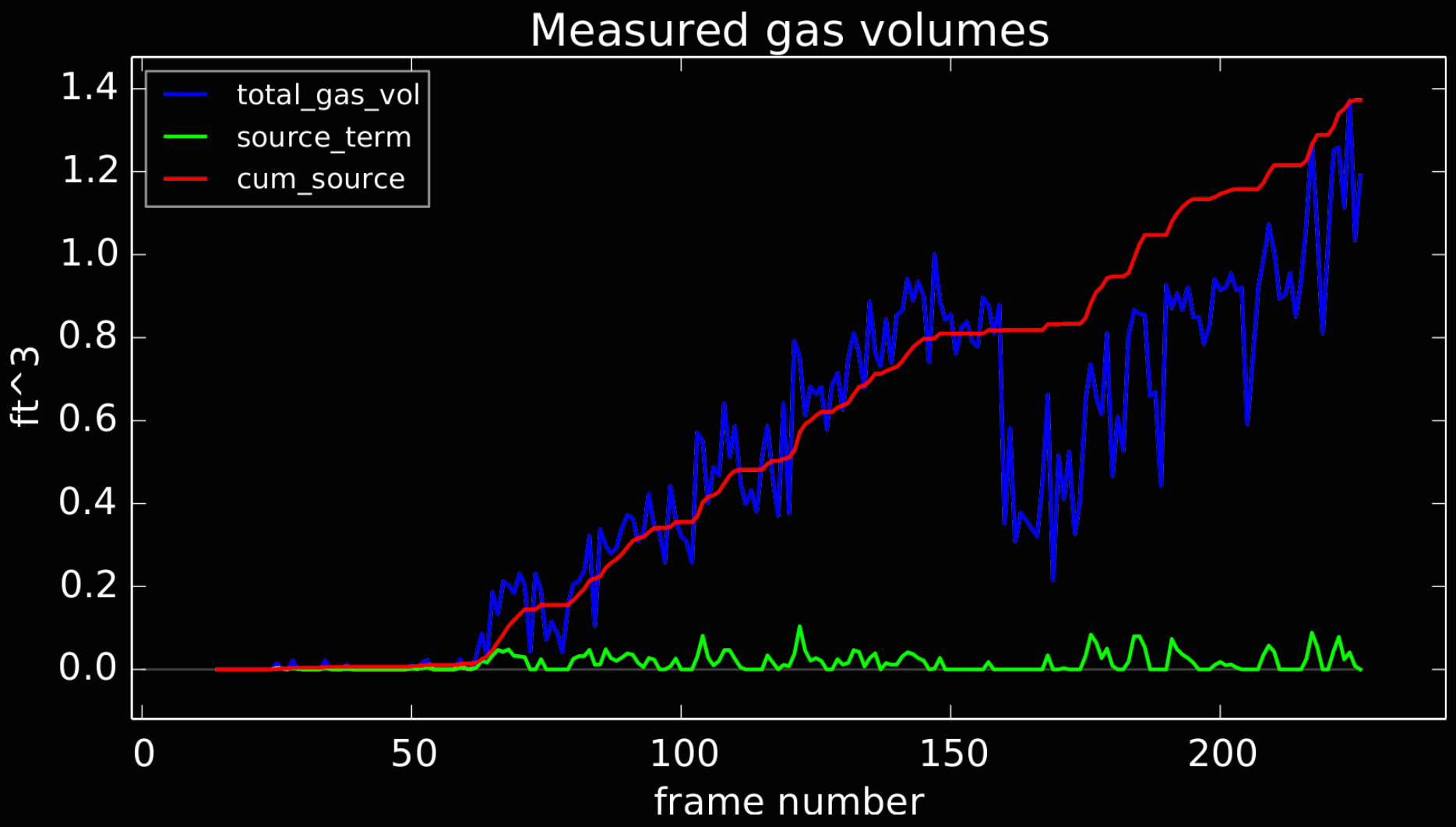


MDLR results

Lab measurements of minimum detectable leak rates (MDLR) for the GCI for measurement distances of 3.4 and 5.9 m, and at different wind speeds of 0, 5, 10 mph, and 15 mph.

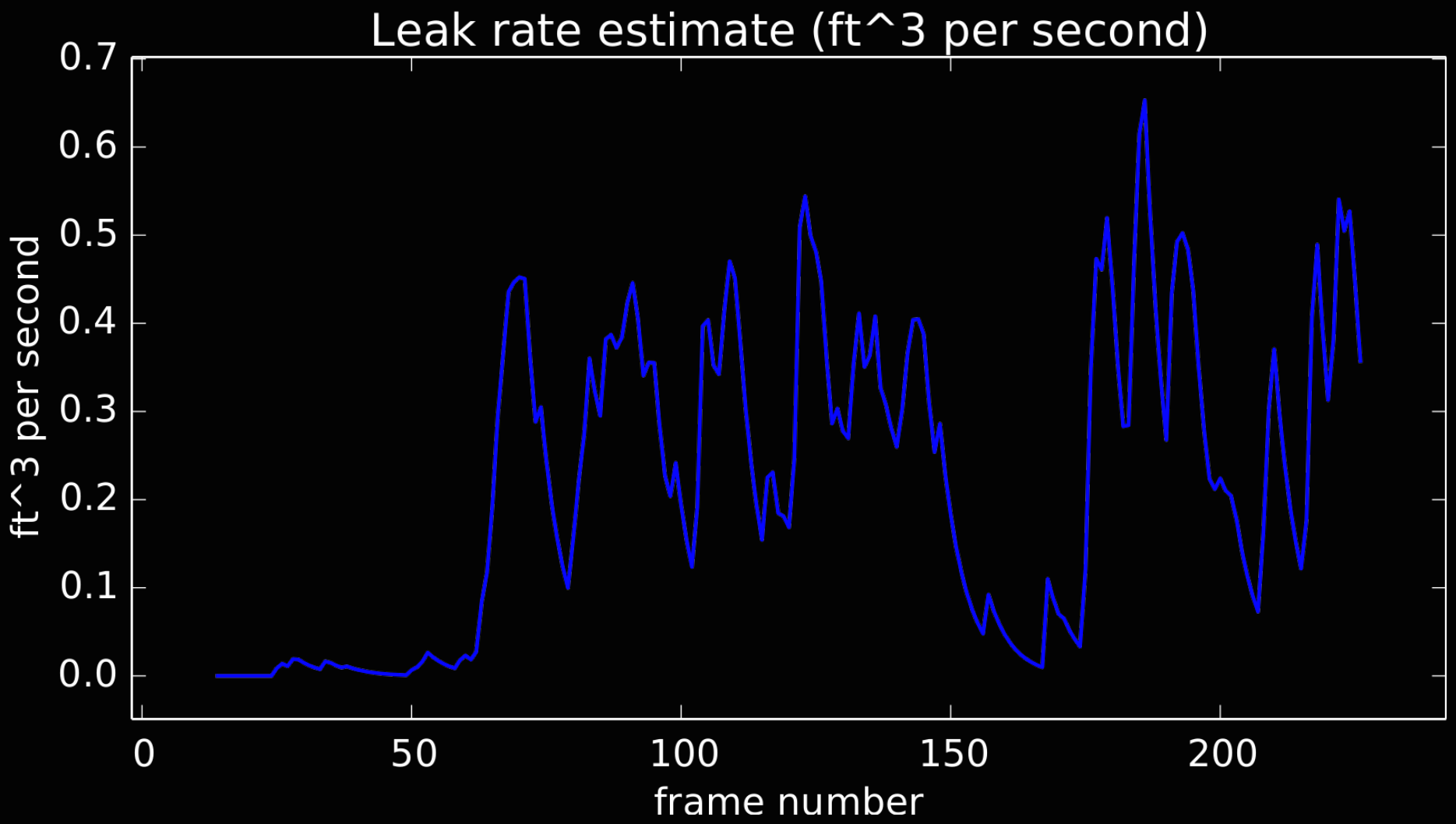
	Dist.	0 mph		5 mph		10 mph		15 mph	
gas	**(m)**	**cc/min**	**g/hr**	**cc/min**	**g/hr**	**cc/min**	**g/hr**	**cc/min**	**g/hr**
Butane	3.4	250	36.0	725	105.0	1650	238.0	$>$ 1650	$>$ 238.0
	5.9	1050	151.0	$>$ 2550	$>$ 368	—	—	—	—
Ethane	3.4	250	18.6	$>$ 4800	$>$ 357	—	—	—	—
	5.9	475	35.3	$>$ 4800	$>$ 357	—	—	—	—
Methane	3.4	250	10.0	900	35.8	4000	159.0	$>$ 7100	$>$ 159.0
	5.9	775	30.9	2450	97.6	7100	283.0	$>$ 7100	$>$ 159.0
Propane	3.4	325	35.5	1100	120.7	2900	316.6	$>$ 3480	$>$ 380.0
	5.9	800	87.3	3480	380.0	$>$ 3480	$>$ 380.0	—	—
Ethylene	3.4	125	8.7	350	24.3	1500	104.0	2500	174.0
	5.9	300	20.9	450	31.3	1250	86.9	1600	111.0
Propylene	3.4	165	17.2	165	17.2	483	50.2	1525	159.0
	5.9	200	20.8	1000	104	2000	208.0	3980	414.0
Iso-Butylene	3.4	125	17.4	275	38.2	600	83.3	1950	271.0
	5.9	145	20.1	500	69.5	750	104.0	1600	222.0

Example of calculating emission rate



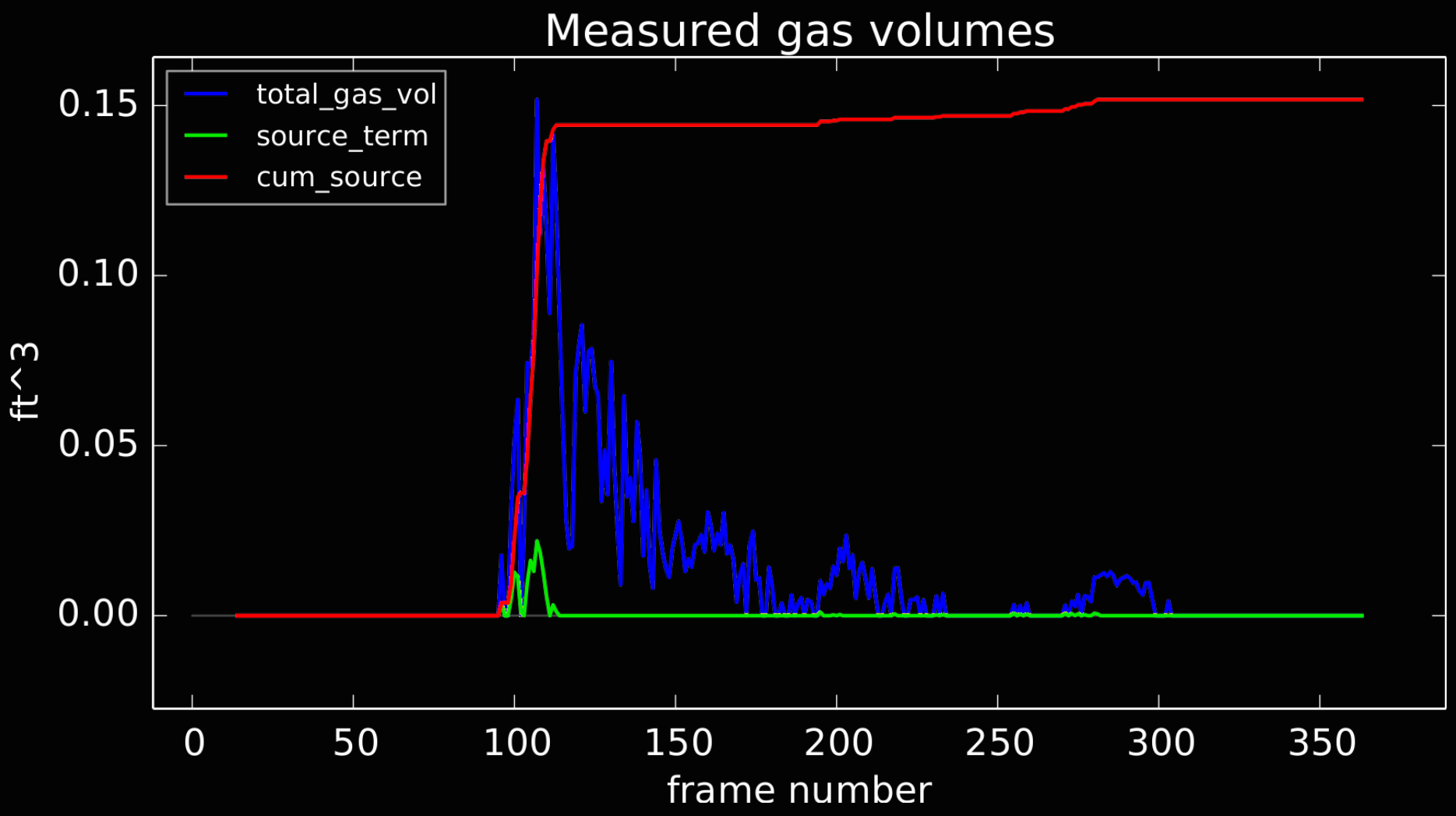
Data: pressure-regulated methane hose release

Example of calculating emission rate



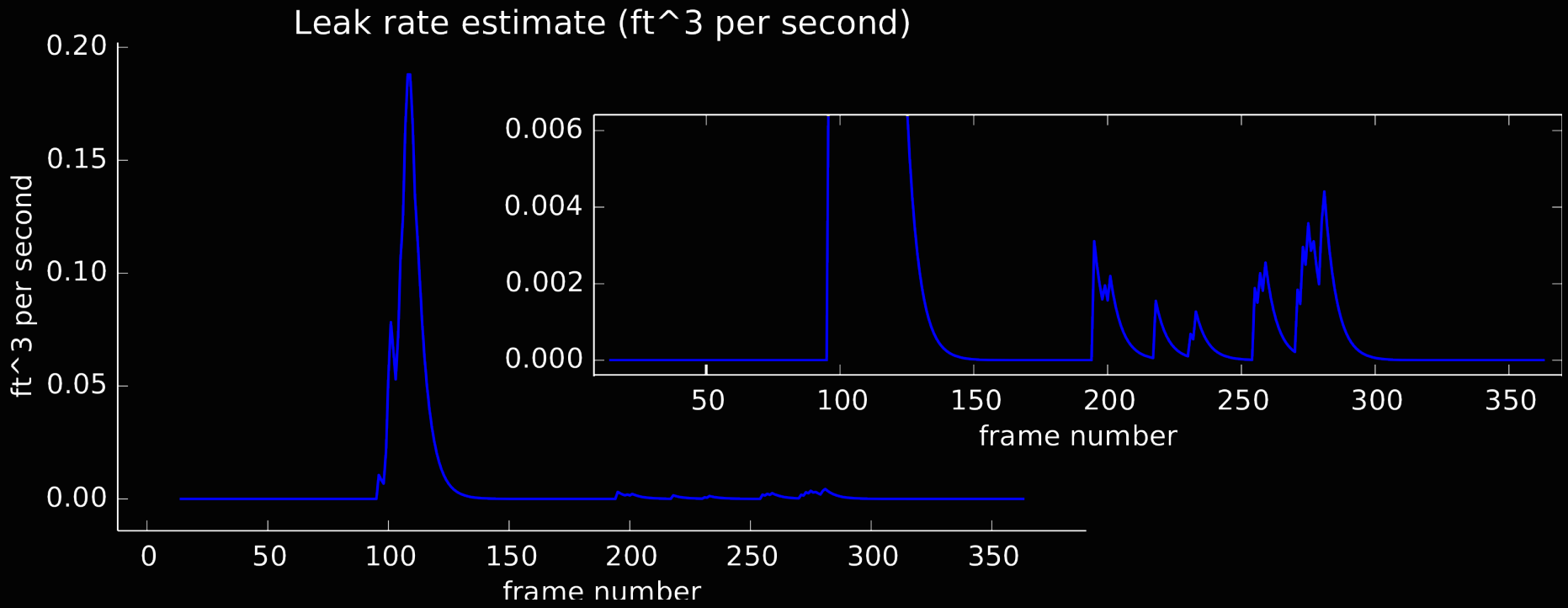
With the hose, we filled a 13 gal bag in about 6 seconds (2.2 gal/sec), giving an estimated flow rate of 0.29 ft^3/sec.

Example 2: 5 lpm propylene flow



Data: mass-flow-controlled propylene release

Example 2: 5 lpm propylene flow



1 liter $= 0.035$ ft^3, so 0.002 ft^3/sec ≈ 3.4 lpm

Conclusion

- 24/7 continuous monitoring
- Alarm report videos
- Emissions quantification